SCS the pactor creators

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Via ECFS
Marlene H. Dortch
Federal Communications Commission
445 12th Street, SW
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December 16, 2019

Reply Comment,
WDT 16-239, RM-11831,

in response to
letters written by Mr. Nelson Sollenberger, KA2C, November 16, December 2, 2019[1,2]

by Hans-Peter Helfert, DL6MAA,
c/o Spezielle Communications Systeme GmbH & Co. KG, Germany

Dear Ms. Dortch,

Referring to Mr. Sollenberger's statements, I would like to discuss and disprove three points of his extensive presentation:

1. Alleged insufficient documentation of the PACTOR protocols.

2. Calculations on the probability of successful PACTOR monitoring in fading channels.

3. Classification of the PACTOR 4 "speedlevels" (waveforms) 1-4 as "spread spectrum system".

[1] https://ecfsapi.fcc.gov/file/11170346002261/FCC%20letter%20RM-11831%20WT%20Docket%20No.%2016-239%20%20Nov%2016%202019%20NRS.pdf

[2] https://ecfsapi.fcc.gov/file/113087596430/FCC%20letter%2016-239%20Dec%202019-2.pdf

1. Documentation of the PACTOR protocols

Mr. Sollenberger claims that the PACTOR protocols are not sufficiently documented within the scope of the legal requirements.

His statement is false.

The extent to which a "technique" used in Amateur Radio needs to be documented in the US can be assessed by the three examples, CLOVER[3], G-TOR[4] and PACTOR[5] (PACTOR-1), which are named in FCC § 97.309(a)(4).

CLOVER and G-TOR are proprietary protocols that are only used in devices of the actual protocol developers. Only PACTOR 1 was implemented by numerous third parties, radio amateurs as well as modem vendors. But even that does not mean that PACTOR 1 is considered completely free of intellectual property and considered as "public domain" protocol. Of course, copyright law continues to apply to PACTOR 1, but in the field of Amateur Radio, we have always allowed radio amateurs to use PACTOR freely, as a common standard for Amateur Radio.

CLOVER and G-TOR are well-documented as proprietary protocols for a basic understanding of the protocols. Nevertheless, the duty of documentation is not about making a simple replica possible, but only about describing the "technical characteristics" of the protocols, ie their modulation types, channel and source coding, their bandwidth and symbol rate, their packet lengths and packet structure, and the ITU emission designator. These details are included in the examples mentioned. PACTOR 2, PACTOR 3 and PACTOR 4 are at least as well described as CLOVER, for example.

The FCC never explicitly stated how much detail is required and never complained to SCS about any of our products during the last 29 years of PACTOR operation, until the false accusations of alleged "effective encryption" filed by Winlink opponents last year. PACTOR 3 was released in 2002, more than 17 years ago.

We are convinced that part 97.309 is not about the complete divulgence of intellectual property, but about the description of the "technical characteristics" of the protocols and, above all, about their readability. The ability of monitoring is equivalent to open speech.

The requirement for complete disclosure of the entire intellectual property in digital protocols used in Amateur Radio is not supported by the IARU[6], either. See 99-3, "Intellectual property

[3] http://www.arrl.org/clover
https://www.tapr.org/pdf/CNC1992-Clover-IIprotocol-W7GHM.pdf
[4] http://www.arrl.org/g-tor
[5] http://www.arrl.org/pactor
[6] http://www.iaru.org/uploads/1/3/0/7/13073366/resolutions_and_policies_jan2019.pdf

rights policy for amateur radio”. Of course, Amateur Radio is not an area devoid of normal civil and legal rights in which any method used must automatically be “public domain” and must be available as “open source”.

Our descriptions of PACTOR 2[7], PACTOR 3[8], and PACTOR 4[9] go far beyond the legally required documentation standard and describe the methods so well that several companies were able to develop monitoring software completely independently of SCS, here are three examples:

- Wavecom Electronik AG[10]
- Hoka Electronics B. V.[11]
- Procitec GmbH[12]

We would like to add that in the last 20 years we have not received a single serious request on details of the PACTOR protocols from the Amateur Radio sector. Apparently, the interest in PACTOR monitoring is very low, in contrast to the representation in RM-11831.

In 2002, when PACTOR 3 was released, the implementation of a sufficiently good monitoring mode on average PC’s with soundcard, ie without dedicated DSP hardware, was hardly possible, at least not without very high effort. The available computing power was simply too low. All of our modems, however, have always provided a monitoring mode that allows you to read all the transmissions that can be generated by the modem[13]. **PACTOR has always been open language.**

PACTOR is even mentioned several times in catalog of questions[14] regarding the amateur radio tests, released by the “Bundesnetzagentur” (BNetzA), the authority responsible for Amateur Radio in Germany. PACTOR is considered as a normal “mode” like CW, PSK31 or SSB voice.

There was not a single regulatory complaint worldwide because of missing or poor monitoring options or insufficient documentation in the last 29 years.
The first publication of PACTOR 1 was made more than 29 years ago, in November 1990.

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7 https://www.p4dragon.com/download/PACTOR-2%20Protocol.pdf
8 https://www.p4dragon.com/download/PACTOR-3%20Protocol.pdf
9 https://www.p4dragon.com/download/PACTOR-4%20Protocol.pdf
10 http://www.wavecom.ch/content/ext/DecoderOnlineHelp/default.htm#!worddocuments/pactor4.htm
11 https://www.hoka.com/products/code300-32-options/pactor-iii.html
12 https://www.procitec.de/files/procitec/pdf/produkte/go2SIGNALS-Decoderlist.pdf
13 https://www.p4dragon.com/download/Update_Info_DR7X00_Version_1_17_English.pdf
14 https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/Amateurfunk/Fragenkatalog/BetriebVorschriftFragKlAuEId7830pdf.pdf?__blob=publicationFile&v=6

Meanwhile, the computing power of available mid-range PC's is now so high that PACTOR monitoring on Raspberry Pi or similar small computers with reasonable effort is possible. As announced in our letter to the FCC[15] from April 15, 2019, SCS has developed and released a freely available monitoring software for PACTOR 1, 2, and 3. In the meantime, PACTOR monitoring is possible very easily and at no extra cost for an SCS hardware modem.

Mr. Sollenberger claims that the assignment of the PACTOR 3 preambles and the function of these preambles is not published in the ITU document ITU-R M.1798-1[16]. The preambles are numbered from 0 to 15, resulting in an implicit mapping of preamble and bit pattern, which was considered intuitively clear.

Regarding the mapping of complex PACTOR 4 modulation types, e.g. QAM16 and QAM32, I want to clarify that the assignment of bit patterns and constellation points was adopted from STANAG 4539 NATO standard, so it is identical to the mapping published there. We will add a corresponding note to the PACTOR 4 documentation.

We have never received a request from Mr. Sollenberger to clarify any protocol details. His letters seem to be concerned only with **portraying PACTOR 3 and PACTOR 4 as non-readable, illegal methods**.

SCS has always met all the legal requirements worldwide. Of course, if a more extensive documentation were demanded by law in the US, SCS would provide an even more comprehensive and accurate description of the protocols. However, we cannot offer all of our implementations as "open source".

I would like to say that we have received absolutely no feedback from the Amateur Radio sector to the freely available monitoring software PMON for Raspberry Pi[17]. Even the interest in this freely available monitoring software seems to be extremely low.

This whole affair now seems to us to be stretched far beyond the reasonable extent due to this very low public interest.

Mr. Sollenberger compares protocols such as PACTOR and the availability of public descriptions of these protocols with worldwide standards such as "Cellular, Wi-Fi, Bluetooth, NFC and many others". This comparison is outlandish in every way. Developers of these standards are consortiums of international corporations that negotiate a standard among themselves. The patent situation is also completely independent of the description of the standards, but here a very precise standardization is necessary because a precise common basis for all companies involved is required.

[15] https://ecfsapi.fcc.gov/file/105082302314368/Rm-11831c.pdf
[16] https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.1798-1-201004-I!!PDF-E.pdf

[17] https://www.p4dragon.com/en/PMON.html

PACTOR 4 was developed by SCS GmbH & Co. KG as a sole proprietorship from 2007 to 2010. SCS is a relatively small company specializing in RF communications with less than 10 employees, currently all members of the SCS staff are radio amateurs. The development of the PACTOR 4 protocol, including the necessary DSP hardware, took about 20 man-years, and thus required a significant portion of the available working time of the developers working for SCS over 3 years. It goes without saying that this development can only make economic sense if the results do not have to be completely "public domain". Such a development was therefore only possible on condition that a certain proportion of the intellectual property contained in the development also remains protected in Amateur Radio.

The development of the PACTOR 4 system is typical of highly specialized Amateur Radio companies: These are usually relatively small and their development can only pay for themselves if at least some of the intellectual property remains protected also in Amateur Radio. Therefore, we strongly oppose the wording in RM-11831 that all procedures used in Amateur Radio must be available as "open source". If this were included in the legal text, smaller companies that develop relatively complex systems for Amateur Radio, are virtually excluded from the Amateur Radio market or at least their ability to carry out such new developments is limited dramatically. **This would appear to greatly damage the future development of amateur radio.**

2. PACTOR monitoring on fading HF channels

Mr. Sollenberger writes 11 pages about the alleged obstacles of monitoring of PACTOR signals on HF fading channel. He apparently has never performed any practical tests using a PACTOR modem himself, and apparently never tested the free Raspberry Pi software "PMON", either, which allows monitoring of all PACTOR 1-3 signals including automatic decompressing of Winlink's LZHUF data compression.

Anyone who knows the real properties of the PMON on real-world channels will immediately notice that there must be false assumptions in Mr. Sollenberger's calculations, also see clarification on the experimental monitoring results by Gordon Gibby[18].

Mr. Sollenberger cannot, for example, suppose that 10 attempts on the "ITU average channel" (which is a hypothetical channel) yield the same average monitoring results as 10 attempts on all possible different channel scenarios. 50 % of the channels have faster fading, 50 % slower fading than the "average channel" (using the "mean value of fading rates") in the mentioned ITU paper[19] on page 305, referring to experiments on 15 MHz performed in Germany. In any case, Mr. Sollenberger cannot argue that a long Winlink message will almost never arrive

[18] https://ecfsapi.fcc.gov/file/1208114581575/InexplicableExperimentalConfusion.pdf
[19] https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-P.266-7-1990-PDF-E.pdf

completely due to fading, although at least10 % of all channels have very slow or almost no fading.

The average over all possible channel scenarios is not identical to the average over all attempts in the average (using the “mean value of fading rates”) channel. Mixing up the statistics leads to completely wrong ideas about the real conditions on shortwave channels.

The packet error probability during PACTOR monitoring is extremely low as soon as an SNR margin of **only a few decibels** is available. You do not need a huge SNR-advantage, as claimed by Mr. Sollenberger. The difference between ARQ “connected” reception and ARQ monitoring is only approx. 3 dB. Regarding real-world HF channels, you have to consider that short dropouts of the signal are corrected and compensated for in almost every case by the error correction code (Convolutional Code with soft-decision Viterbi decoding), so that a small percentage of corrupted bits is irrelevant for monitoring. The argument that a single faulty bit would already lead to total failure of monitoring is misleading. Short bursts of errors, e.g. by “statics”, are almost always corrected automatically.

3. Why PACTOR 4 is not a Spread Spectrum System

PACTOR 4 is by definition an Automatic Repeat Request (ARQ) data transmission protocol with a fixed bandwidth of 2.4 kHz. This bandwidth is utilized very well over a wide SNR range of -18 to +17 dB (noise reference bandwidth 2.4 kHz). The ITU Emission Designator is 2K40J2D.

In principle, an ARQ protocol should not significantly change the actual bandwidth of its transmission sub-modes depending on the SNR.

If the bandwidth varies a lot, there is a high risk that **unnecessary collisions will occur**: Other users of the service might mistakenly interpret parts of the 2.4 kHz radio channel as “free” as long as a narrower waveform is used during the ARQ connection. As soon as the signal-to-noise ratio on the PACTOR 4 channel improves again, the use of the wider modulation would then lead to a collision.

Therefore, PACTOR 4 **always uses the same symbol rate** of 1800 symbols per second (sps) (except “speedlevel” 1 with chirp modulation) and therefore **always the same bandwidth**. These 1800 sps are always shaped by using a “root raised cosine” impulse filter with a rolloff factor β of 0.33. Just how the I / Q input values are generated for the modulator differs from “speedlevel” to “speedlevel”.

The signal therefore always sounds almost the same over the entire working range, always looks almost the same on the spectrum analyzer - and thus is largely independent of the currently existing signal-to-noise ratio on the actual ARQ traffic channel. This was a very desirable feature and a requirement in the development of the PACTOR 4 protocol as further explained below. It allows common preprocessing (e.g. interference detection and removal) of the signal and also using the same basic modulator/demodulator section - and as described above also is a very useful feature for collision avoidance. Furthermore, this feature eases identifying PACTOR 4 by ear in the monitoring case.

The 9 different 1800 sps waveforms ("speedlevels") utilized by PACTOR 4 are designed to **make optimal use of the constant symbol rate of 1800 sps over a wide SNR range**.

The constant bandwidth allows for a better behavior of the system on dispersive multipath channels at low SNR's. Dispersive means that the ionospheric channel has not flat frequency response but frequency-selective fading occurs. I will explain this in more detail below. Unfortunately, Mr. Sollenberger's statements about the "BTI" (ratio of bandwidth to user data rate) defined by him are not useful in HF practice. In principle, if all BTI greater than 8 were banned, constant-bandwidth ARQ would only be allowed down to an SNR of about -6 dB. This would be an enormous limitation for the experimental field of reliable and robust data communication in the 2.4 or 2.8 kHz wide SSB channel!

This statement is relatively easy to deduce from Shannon Hartley's Law:

C	channel capacity in bit/s
B	signal bandwidth
ld	logarithm with base 2
S	signal power
N	noise power
P	gap ("penalty") between theoretical channel capacity and the transmission rate achievable by the real-world system. An optimistic but still realistic value on multipath shortwave channels for this value is P = 0.4 (-4 dB), as efficiency factor between real-world system and theoretical limit.
SNR	log(S/N);

SNR calculation depending on BTI:

$$\frac{C}{B} = ld\left(1 + \frac{S}{N} * P\right); \qquad (1)\ Shannon\ Hartley's\ Law, extended\ by\ penalty\ P.$$

$$\frac{C}{B} = \frac{1}{BTI}; \qquad (2)\ Definition\ of\ BTI.$$

$$ld\left(1 + \frac{S}{N} * P\right) = \frac{1}{BTI}; \qquad (3)\ Equation\ (1) = Equation\ (2).$$

$$\frac{S}{N} = \frac{2^{\frac{1}{BTI}} - 1}{P}; \qquad (4)\ Equation\ (3)\ solved\ for\ \frac{S}{N}.$$

$$SNR = \log\left(2^{\frac{1}{BTI}} - 1\right) - \log(P)\,; \qquad (5)\ Log\ equation\ (4).$$

Using a BTI = 8 and P = 0.4 (-4 dB) yield an SNR of:

SNR = -10.4 dB + 4 dB = **-6.4 dB**;

This means that below of an SNR of -6.4 dB, on Sollenberger's arbitrary definition of a "spread spectrum system", a real-world ARQ system would be forced to reduce bandwidth in order to achieve better SNR. As noise power N can be calculated as a product of spectral density of the noise **η** and bandwidth B, lower bandwidth will improve the effective SNR. Nevertheless, any methods that still work below an SNR of -6.4 dB at given bandwidth B would not be allowed anymore.

PACTOR 4 works down to an SNR of -18 dB @ 2.4 kHz, using so-called Memory ARQ[20] (MARQ), i.e. automatic repetition coding (weighted summation of subsequent packets). On a fluctuating channel, you simply do not know how much additional redundancy (or signal energy) currently is required for successful decoding. Reducing the bandwidth to a certain value is not a good way of dealing with that problem – but you can automatically collect signal energy by summing up subsequent packets until the effective SNR is sufficient. MARQ was introduced to Amateur Radio by SCS in 1990. Original PACTOR 1 modems already built on MARQ for good weak signal performance. All PACTOR protocols are optimized for utilizing MARQ. The method later was adopted by many HF modem vendors, e.g. Kantronics[21]. That very nice possibility of Memory ARQ would also be banned by Mr. Sollenberger's suggestions.

All adaptive ARQ systems with <u>constant</u> bandwidth B would no longer be permitted at SNR's worse than -6.4 dB within that bandwidth.

In our opinion, this is an unacceptable and arbitrary restriction on the experimental nature of Amateur Radio.

A wider signal offers a higher overall reliability on dispersive fading channels compared to the narrowband equivalent especially if combined with strong coding with coding rates below ½. This field of experiments should not be banned due to an arbitrary new restriction introduced by Mr. Sollenberger, because he apparently dislikes modes like PACTOR 4.

Of course, the modulation of the PACTOR 4 "speedlevels" 2-4 can be interpreted formally as spread modulation with a spreading factor of 8 or 16. Mr. Sollenberger has taken up this theoretical point of view, **without looking at the practical system as a whole**.

[20] https://ieeexplore.ieee.org/document/765006
[21] https://kantronics.com/wp-content/uploads/2018/10/KAM-XL-Manual-RevE.pdf

The effective payload rate naturally decreases as the SNR decreases (Shannon Hartley). Finally, every payload symbol in PACTOR 4 can no longer be represented by a single 1800 bps symbol, but more energy is required for successful transmission. PACTOR 4 solves this problem by sending a vector of 8 or 16 such symbols instead of a single symbol. This can also simply be considered as **repetition coding**. Voice and CW operators have been doing the same for scores of years, repeating phrases in bad conditions. This is nothing new in amateur radio. The payload symbols are transmitted 8 times or 16 times repeatedly, as identical symbols, but each rotated by a certain phase value in order to keep the spectrum flat and preserve the favorable properties of the signal. These vectors are always the same and defined as rows of 8 or 16 fixed, complex values in the public PACTOR 4 protocol information.

Nevertheless, this way to keep the signal bandwidth constant has nothing to do with a proper spread spectrum (SS) system, which was apparently the intent of the FCC definitions in Part 2.1(c). The spreading factors alone are too low for fundamental features of true SS systems - and the practical use of the protocol itself has nothing to do with a spread spectrum system, either! We do not know any SS system that only spreads the signal if the SNR drops below a certain threshold. Usually an SS system always is an SS system, independent of the SNR. If the system cannot be considered as SS under certain SNR's, this indicates that the overall system is not designed to be a spread spectrum system.

Spread spectrum systems typically use spreading factors of 512 or higher (e.g. IS-95), especially in the CDMA case. Only then it is possible, through the achievable "processing gain", that **several SS subscribers can work virtually without mutual interference on the same, wide channel** (CDMA). This is completely **absurd with spreading factors of 8 or 16!** Parallel operation, so a fundamental SS property, is of course not possible with these PACTOR 4 waveforms and not feasible at all. The theoretically achievable "processing gain" is 9 or 12 dB. This is not sufficient to allow parallel operation on a fading HF channel. Classifying the PACTOR 4 "speedlevels" 1-4 as SS seems to us a formal sophistry to portray PACTOR 4 as inadmissible, against any pragmatic and realistic assessment. Common sense tells you that PACTOR 4 has nothing to do with a spread spectrum system. It simply is an adaptive ARQ system that utilizes constant symbol rate and constant bandwidth over its entire working range.

For PACTOR 4, sending symbol vectors instead of single symbols is all about making the most of the available 2.4 kHz bandwidth, even at low noise margins. This is definitely not about the AWGN channel, which appears to be the primary channel mentioned by Mr. Sollenberger in his argument, but **only to the behavior of the modulation under the conditions of a shortwave channel with multipath propagation and frequency-selective fading!**

Such shortwave channels are exactly described in ITU-R F.520-2[22] and F.1487[23] and can be modeled in software. PACTOR 4 was developed with the aim of achieving the best possible throughput on those dispersive HF fading channels, even at low noise margins. To do this, the multipath channel must be "resolved". The demodulator must be capable of identifying all delayed signal components of the ionospheric channel. This is only possible with sufficient bandwidth. The resolution of the analysis improves with the available bandwidth and roughly can be approximated as $\tau = 1/B$, see ITU-R P.1407-6[24]. Larger bandwidth means more accurate time resolution of the channel impulse response. The "spread" PACTOR 4 waveforms allow to identify separate multipath components of the channel spaced by time τ. The delay spread of most shortwave channels is only a few milliseconds long. A 2.4 kHz wide channel already allows to resolve many separate paths within this time span. It is thus known to the demodulator which paths via the ionosphere are currently contributing to the received signal and which delays and amplitudes these paths have, relative to each other. With this information, it is then possible to **constructively superimpose** the entire signal energy on dispersive shortwave channels. The partial signals are always added up "constructively", i.e. without mutual attenuation due to different phase angles. This method of collecting the signal energies of all contributing signal paths is called RAKE receiver. Of course, true SS systems also exploit this possibility and also use RAKE receivers. However, the use of a RAKE receiver does not indicate that the protocol automatically is a spread spectrum system, at best, that the waveform is sufficiently wide to resolve the channel. The PACTOR 4 "speedlevels" 5-10 also resolve the channel, although they are not considered "spread" by Mr. Sollenberger. At high SNR's, however, it is possible to determine the channel impulse response by interspersing short training sequences. This is no longer possible at low SNR's.

In the most narrowband systems, due to the destructive interference of the multipath components, very deep fading may occur, in which the signal completely disappears. This is not possible with a wider system that can identify and constructively overlay the multipath components. This property is a decisive advantage of the 2.4 kHz wide system over the comparable narrowband system. Of course, if the delay between of ionospheric paths is less than 1/B, the paths cannot be resolved – and the channel still appears to be a Rayleigh fading channel. Nevertheless, the probability of deep fades of the overall signal decreases dramatically with a 2.4 kHz wide signal compared to the narrowband equivalent. This also means that monitoring of a 2.4 kHz wide signal is less susceptible to narrowband fadeouts.

This advantage is not mentioned by Mr. Sollenberger in his two, overall more than 30 pages long, letters. His statements on the "gap" of the Shannon limit in the power-constrained case, especially the minor advantage of wider signals, apply only to the AWGN channel. For a dispersive shortwave channel, these simple relationships, which Mr. Sollenberger explain in his second letter, do not apply.

[22] https://www.itu.int/dms_pubrec/itu-r/rec/f/R-REC-F.520-2-199203-W!!PDF-E.pdf
[23] https://www.itu.int/dms_pubrec/itu-r/rec/f/R-REC-F.1487-0-200005-I!!PDF-E.pdf
[24] https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.1407-6-201706-S!!PDF-E.pdf

The wider system will always yield a significantly higher throughput in such dispersive shortwave channels than the narrowband system, although both systems in the AWGN channel basically have the (almost) same properties. This is the crucial technical reason for using 2.4 kHz waveforms in PACTOR 4 even at lower SNR’s; apart from the basic wish to keep the bandwidth constant during an ARQ connection.
Transmitting messages at a significantly higher effective throughput using the same signal power may be very important in an emergency, using less than excellent antennas, and working with limited power and signal in an emergency shelter. This really does happen, i.e. is not a hypothetical discussion.

The use of 2.4 kHz wide waveforms even at low SNR’s leads to significantly higher average throughput rates on real, dispersive shortwave channels using the same signal power.

Mr. Sollenberger uses the word “overpower” 12 times in his two letters. We wonder what concern led Mr. Sollenberger to his comments on PACTOR 4. The fear that narrowband modes are “overpowered” by PACTOR 4 is completely unfounded. Without further preprocessing, such as notch filters, the 2.4 kHz wide waveforms would be even more susceptible to strong narrowband noise (eg carriers due to intermodulation in the receiver or local interference by switching power supplies, etc.) than the comparable narrowband system. Mr. Sollenberger even seems to have the worry that automatic notch filters in the receiver further increase the risk of “overpowering”. It cannot be taken seriously that even automatic notch filters pose a threat to Amateur Radio as soon as 2.4 kHz wide waveforms are used.

If PACTOR 4 was a proper spread spectrum system, the spectral power density would decrease accordingly by the signal broadening to such an extent that much less power would fall into the used spectrum of the narrowband applications, and the mutual interference would also drop dramatically, but in our case of spreading factors 8 or 16 the “processing gain” is as low as only 9 or 12 dB (10 * log(16)), respectively . Nevertheless, the supposed advantage for PACTOR 4 would also be an advantage for narrowband applications, but these gains are so small that there is no real advantage in practical use. Mr. Sollenberger at least claims that narrowband applications are disrupted by PACTOR 4. On the other hand, he claims that PACTOR 4 would have an advantage due to the spread. This argument is one-sided.

The argument that the spread would have a significant advantage in narrowband interference, in practice is not tenable: The signal held at a 2.4 kHz bandwidth has an 8 or 16 times higher probability that a random narrowband interferer appears within the used bandwidth - compared to the equivalent narrowband system that could carry the same amount of data in the AWGN channel. The processing gain of max. 9 or 12 dB is of little help here especially if the interferer is much stronger than the desired signal. In that extreme case, demodulation will be completely corrupted in both scenarios, 2.4 kHz and extreme narrowband – if the noise signal hits the signal passband. The probability for this worst case is 8 or 16 times higher in the 2.4 kHz scenario, respectively. This is definitely not a good choice for avoiding complete

ARQ link failures due to strong narrowband interference. Spreading of the modulation by a low spreading factor definitely is not done in order to avoid PACTOR 4 being destroyed by a CW signal.

For mitigating narrowband interference, an adaptive ARQ protocol also could use narrowband modulation (within the bandwidth of 2.4 kHz) and just modulate only a few OFDM carriers, depending on the measured SNR on each subcarrier, and even could sidestep interference. That would be much more effective for that particular goal than 2.4 kHz serial waveforms as used on P4. However, as already mentioned, the 2.4 kHz P4 waveforms for low SNR's are not about the suppression of narrowband interference, but only about optimum throughput in the case of multipath propagation. In other words, the low speedlevels of PACTOR 4 were not designed with the thought of dealing with potentially interfering signals, they were designed to at least get the information through in a horrible channel condition, thus by the definition of Part 2.1(c), they are simply not spread spectrum.

PACTOR 4 was mainly developed to **optimize throughput on real HF channels**; "commercial" channels (channels outside of Amateur Radio bands) usually are "clean". Random PSK31or FT8 is not common there. Nevertheless, suppressing narrowband interference also was considered (automatic notch filters) but never was the goal of the PACTOR 4 development.

PACTOR 4 has been used worldwide on Amateur Radio bands since 2010, except in the US. There has not been a single regulatory complaint about PACTOR 4 from any country in the world.

Apparently, there is no potential for any problems. PACTOR 4 is a state-of-the-art ARQ technique that uses advanced methods, such as adaptive equalizing and RAKE receiver, to get the most out of shortwave channels and maximize data throughput with the available signal energy. This has nothing to do with trying to "overpower" other participants.

In principle, the Amateur Radio community should draw up and use a band plan within the self-regulation, which assigns separate band segments to broadband and narrowband methods. Collisions can be avoided.

Of course, it would be possible to replace the lower 4 "speedlevels" of the PACTOR 4 protocol by waveforms that are used in PACTOR 3 at low SNR's. However, this would mean that only in the US a sub-optimal PACTOR 4 variant (P4-USA) would have to be used. This would only result in lower effective throughput and probably also in compatibility issues. We do not think that this really is in the spirit of Amateur Radio.

If the FCC will not classify PACTOR 4 as non-spread-spectrum, might you please indicate if using PACTOR 3 lower speedlevels (1-4), as an inferior replacement, would make PACTOR 4 acceptable?

We do not understand why Mr. Sollenberger is so biased about PACTOR 4. To us this appears to be an attempt to prevent a modern shortwave ARQ protocol that was expressly designed to favor the Amateur Radio users by purely formal arguments that have no practical relevance. This should not be supported in our opinion.

We kindly ask you to clarify that PACTOR 4, at FCC's discretion, is not a spread spectrum system.

Respectfully,

Hans-Peter Helfert
SCS GmbH & Co.KG